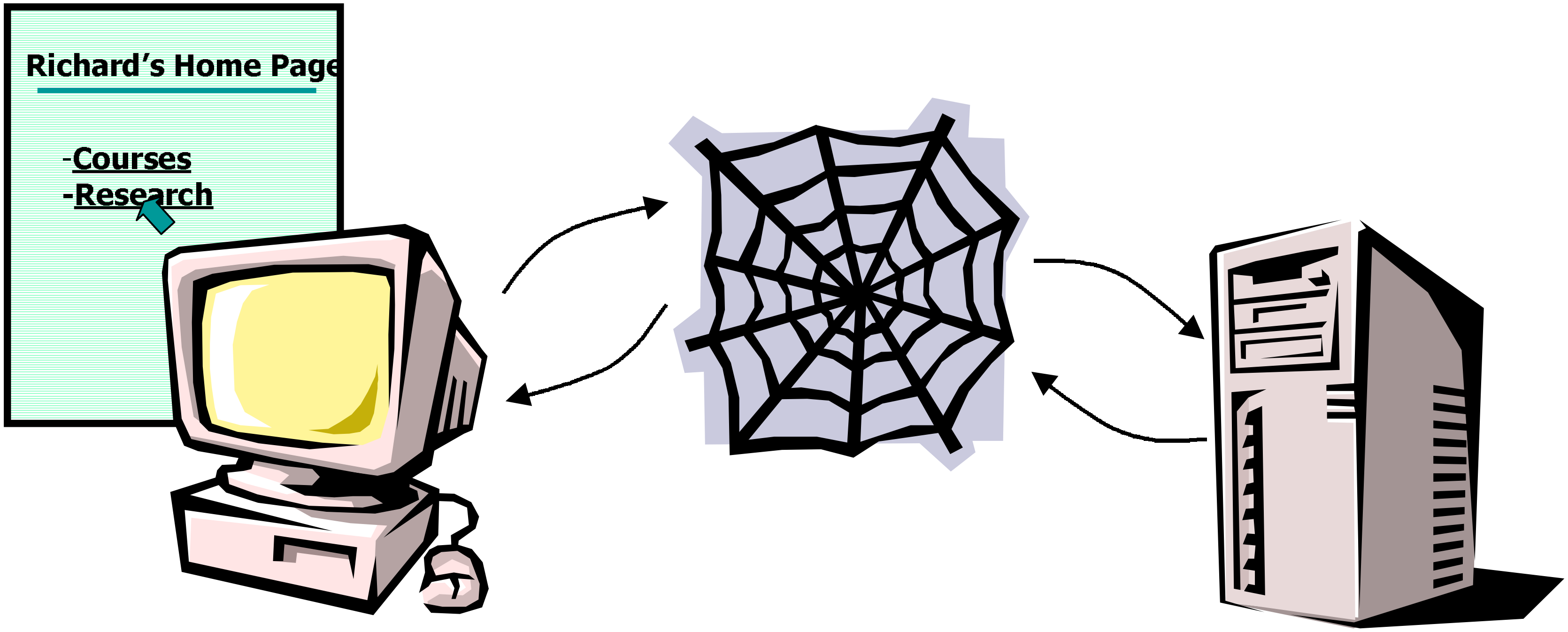
Communication

Sockets (Haviland – Ch. 10)

Simple Web Request

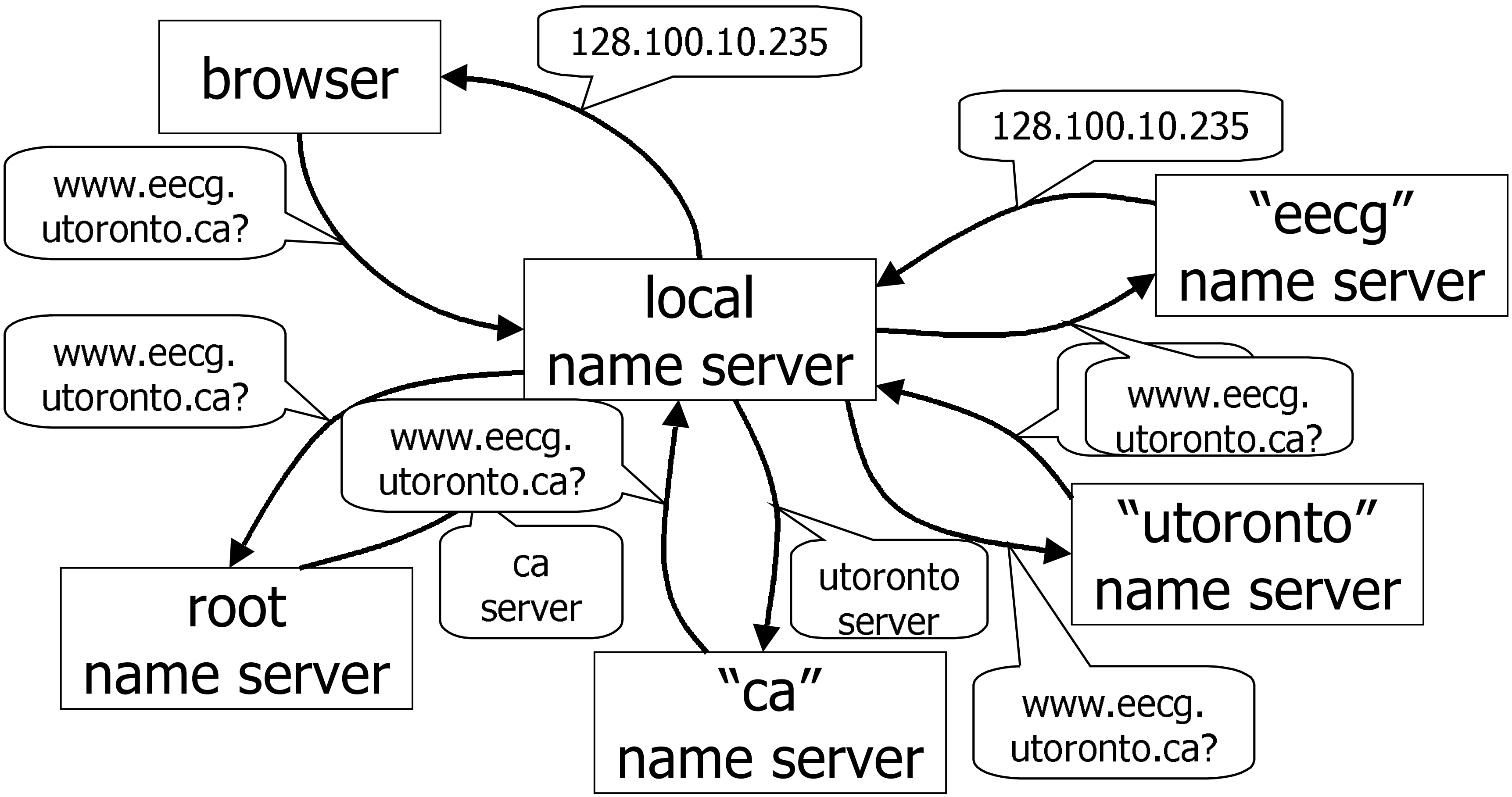


How do we find the server?

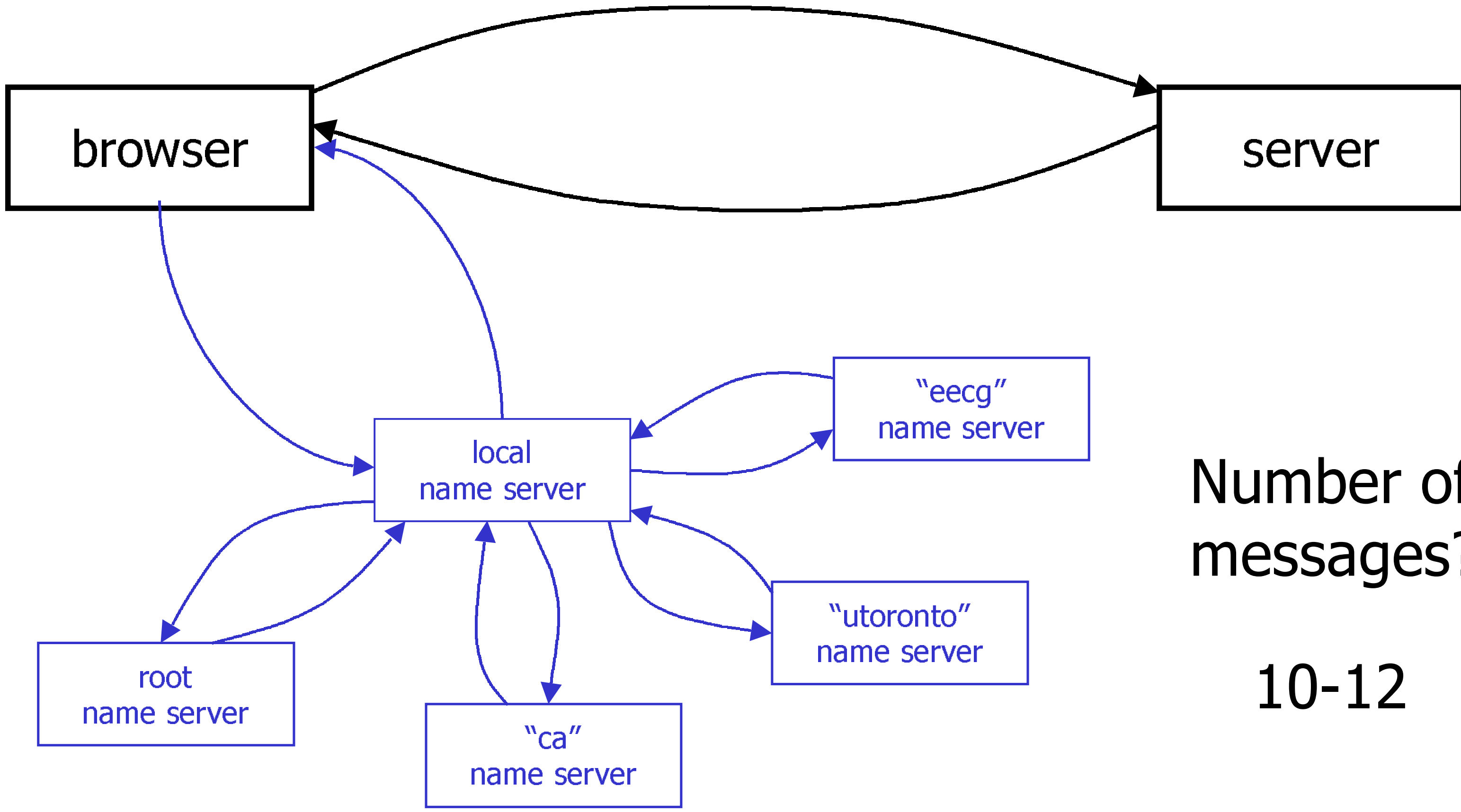
- Every computer on the Internet has an Internet address.
- Called an IP address (Internet Protocol)
- An IP address is four 8-bit numbers separated by dots.

www.eecg.toronto.edu = 128.100.10.235

Domain Name Servers



This is getting complicated!



Number of messages?

10-12

Protocols

Invoice:
Customer: John Doe
Order No: 5379

Qty:		Unit Price	Total
1	Athalon	219.00	219.00
2	128 MB	149.95	299.90
		Subtotal	518.90
		Tax	77.84
		TOTAL	596.74

John Doe Feb 18, 2004

Payable to: CPUS are us $596.74
Five hundred ninety six 74/100

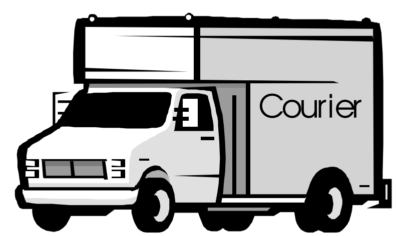
____

CPUS are us

John Doe
Dept. of Computer Science
University of Toronto

John Doe

CPUS are us
0 College Street
Toronto Ontario M5S 3G4

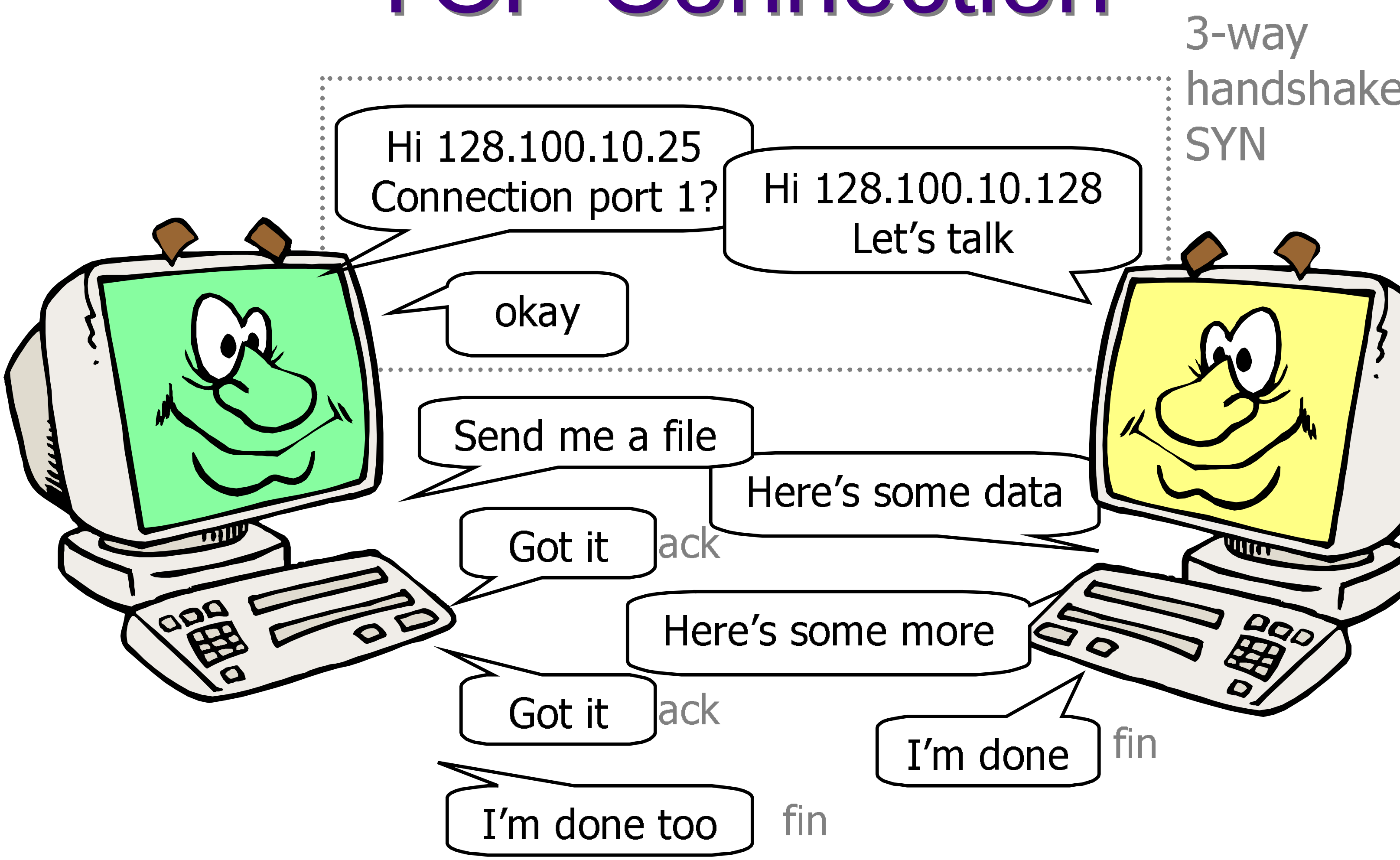


TCP/IP

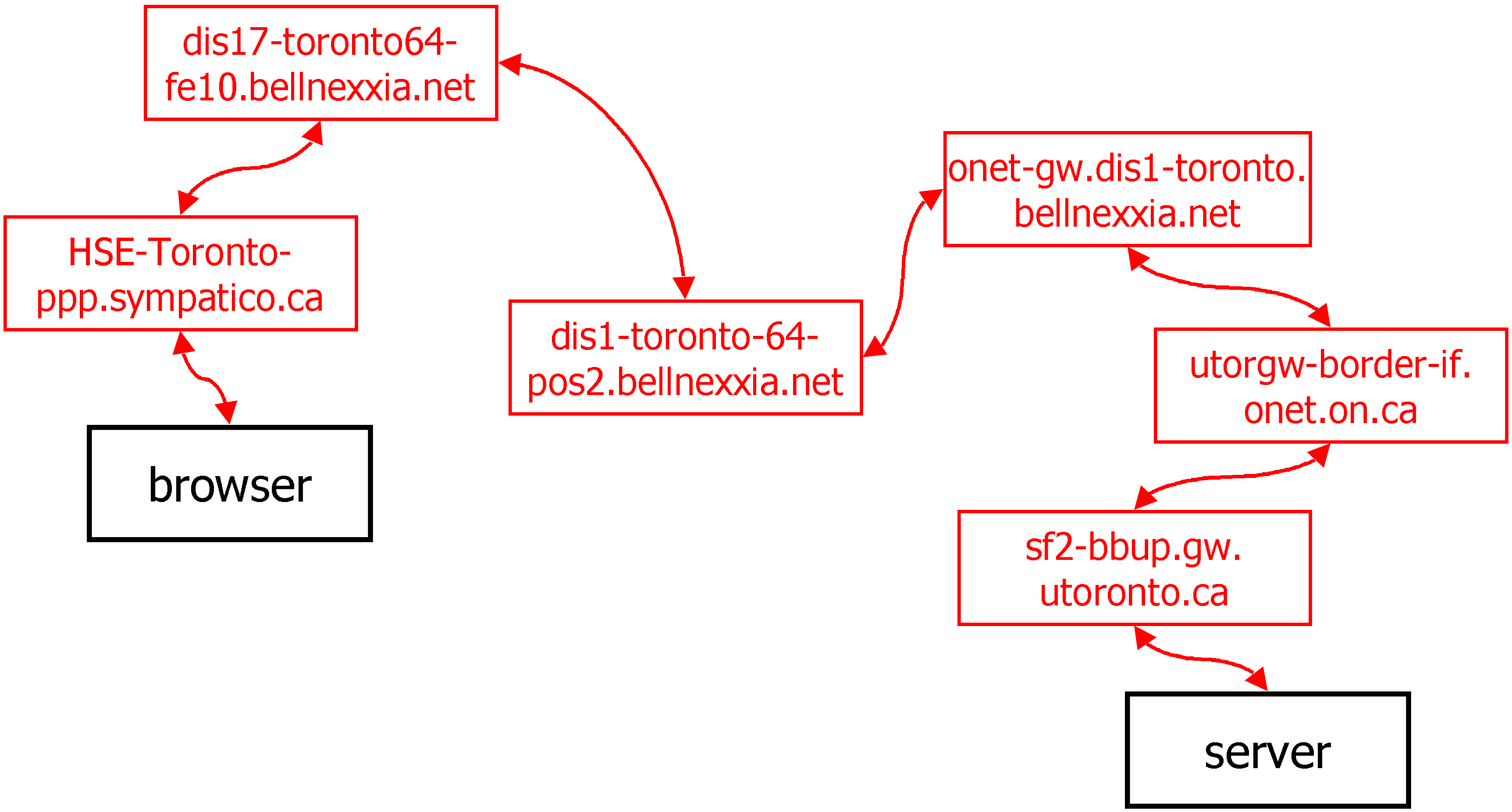
- Transmission Control Protocol.
- Tells us how to package up the data.

<table>
<tr><td colspan="2">source address</td><td>dest. address</td></tr>
<tr><td>bytes</td><td>ack</td><td>port</td></tr>
<tr><td colspan="3">data</td></tr>
</table>

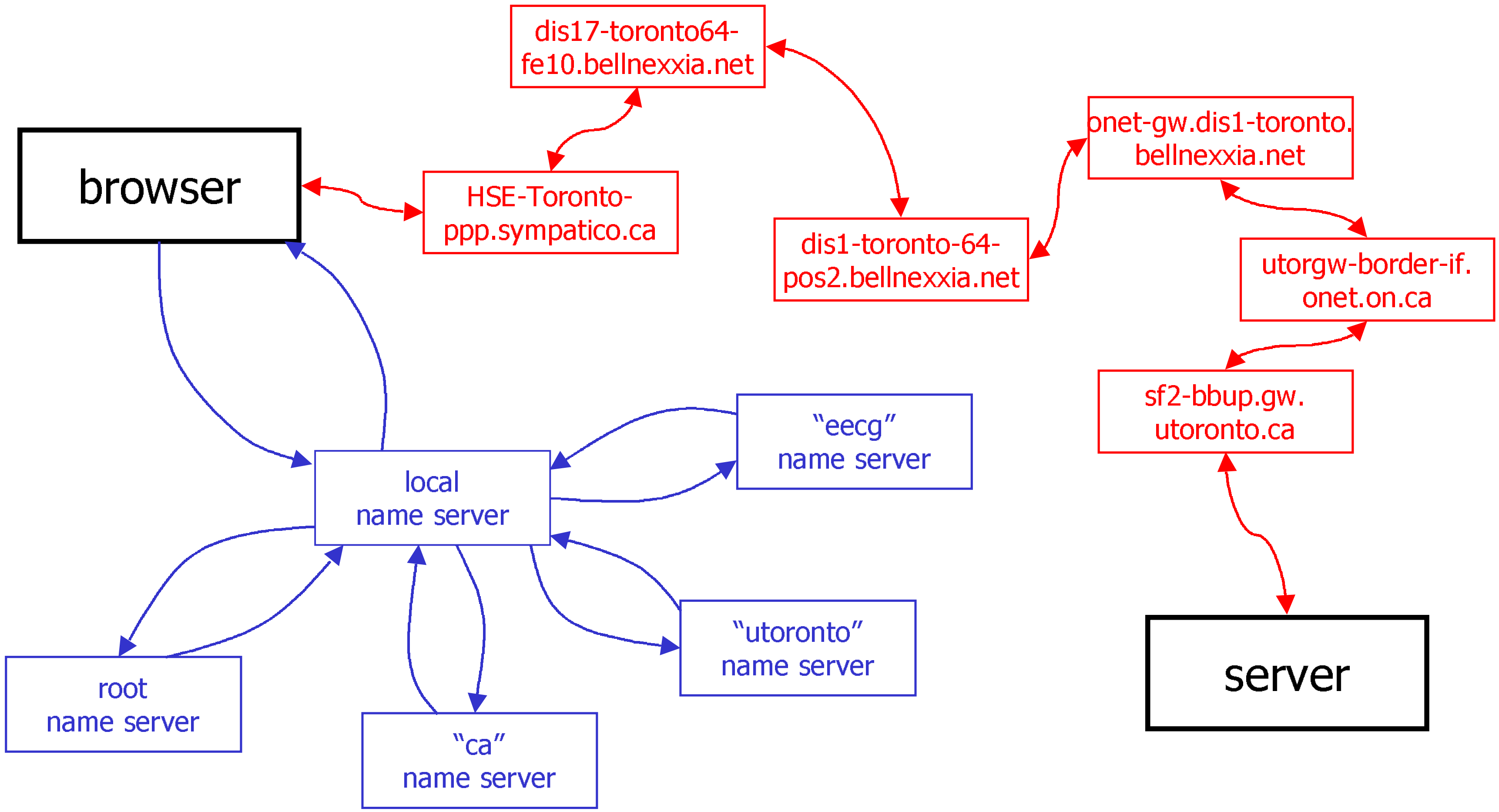
TCP Connection



Routing


dis17-toronto64-
fe10.bellnexxia.net
HSE-Toronto-
ppp.sympatico.ca
browser
dis1-toronto-64-
pos2.bellnexxia.net
onet-gw.dis1-toronto.
bellnexxia.net
utorgw-border-if.
onet.on.ca
sf2-bbup.gw.
utoronto.ca
server

Putting it together

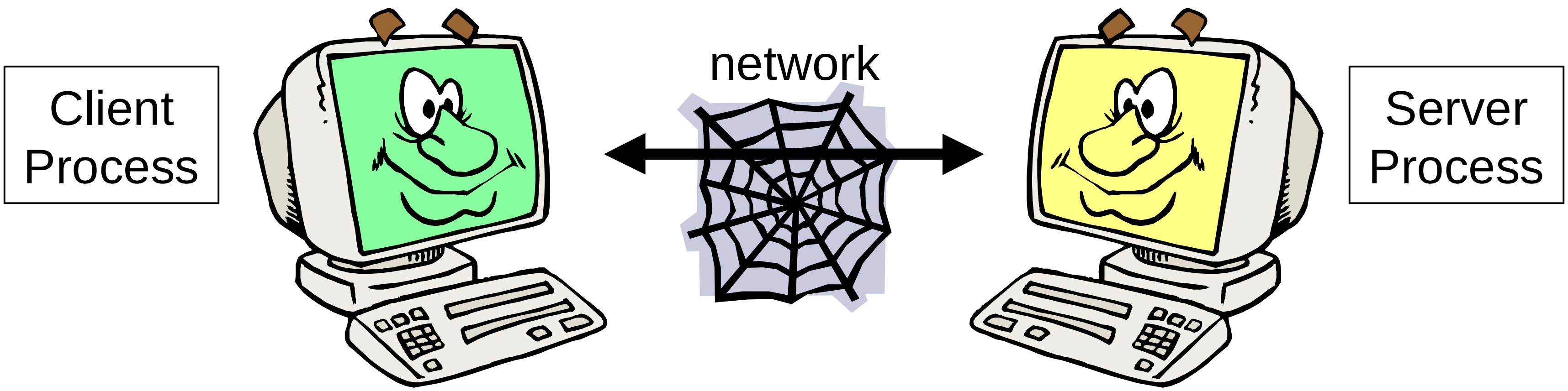


How many messages?

- It depends on the size of the web page we retrieve.
- If the web page is 75 Kbytes (small!) it will be broken up into 103 IP packets.
- Remember DNS took 10 messages

10 + 103 x 7 hops = 731 messages!

The Big Picture

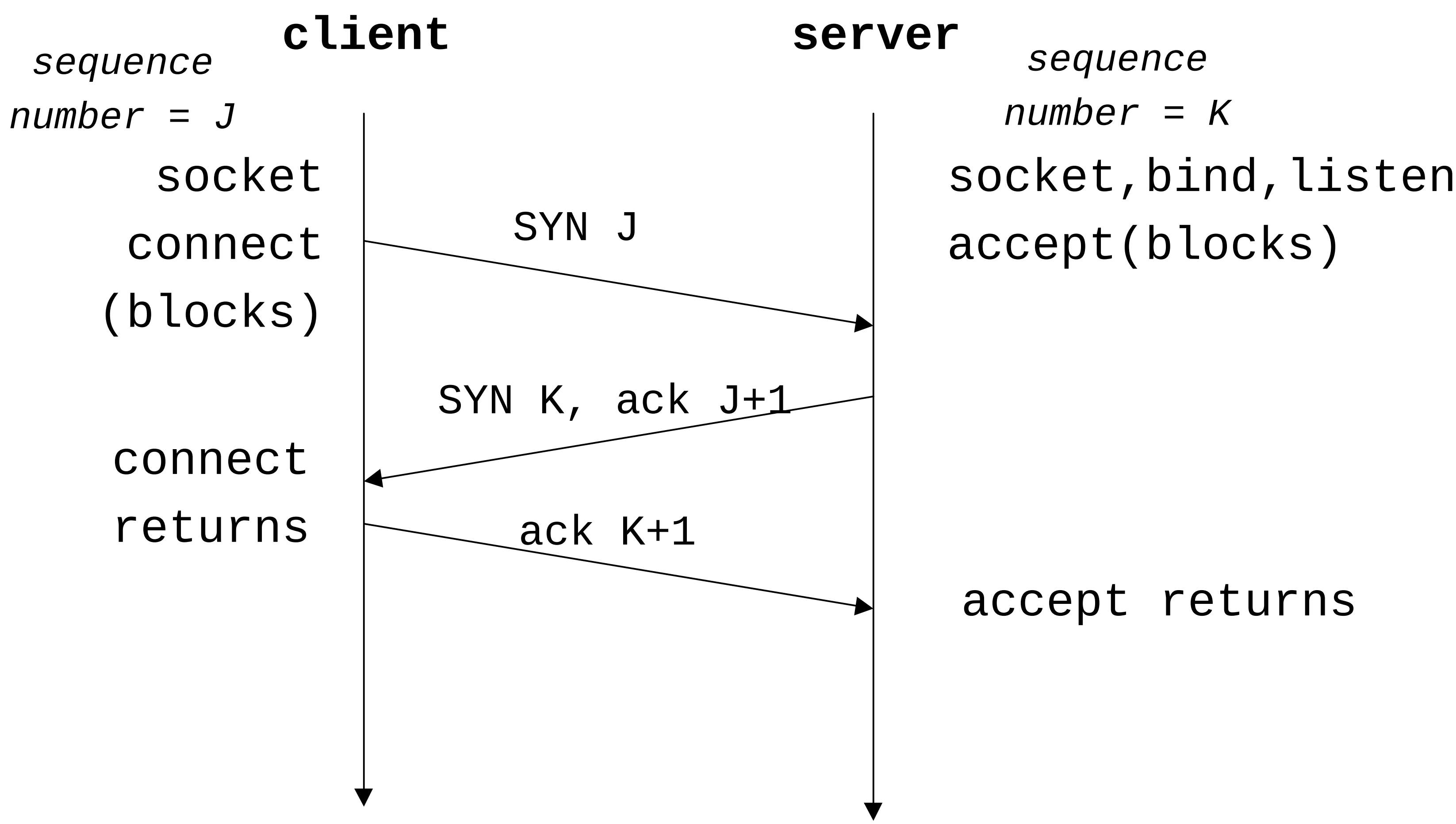


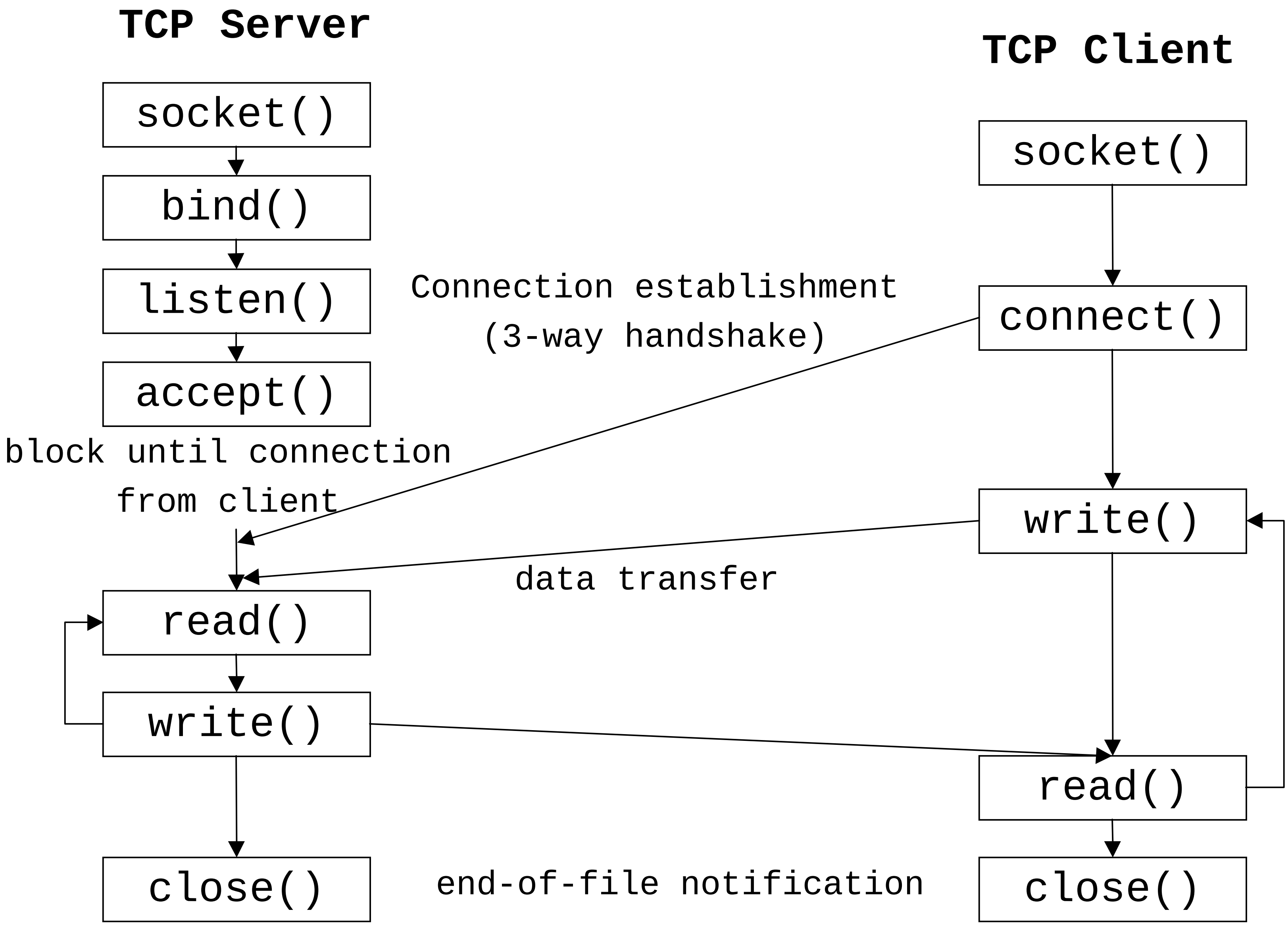
- **Client-Server model**: a client process wants to talk to a server process
- Client must find server - **DNS lookup**
- Client must find process on server - **ports**
- Finally **establish a connection** so two processes can talk

Sockets

- One form of communication between processes.
- Similar to pipes, except sockets can be used between processes on different machines.
- Use file descriptors to refer to sockets.
- Built on top of TCP layer

TCP: Three-way handshake




TCP Server
TCP Client
socket()
bind()
listen()
accept()
block until connection
from client
Connection establishment
(3-way handshake)
socket()
connect()
write()
data transfer
read()
write()
read()
close()
end-of-file notification
close()

Connection-Oriented

Server

- Create a socket: `socket()`
- Assign a name to a socket: `bind()`
- Establish a queue for connections: `listen()`
- Get a connection from the queue: `accept()`

Client

- Create a socket: `socket()`
- Initiate a connection: `connect()`

Socket Types

- Two main categories of sockets
  - UNIX domain: both processes on the same machine
  - INET domain: processes on different machines
- Three main types of sockets:
  - `SOCK_STREAM`: the one we will use
  - `SOCK_DGRAM`: for connectionless sockets
  - `SOCK_RAW`

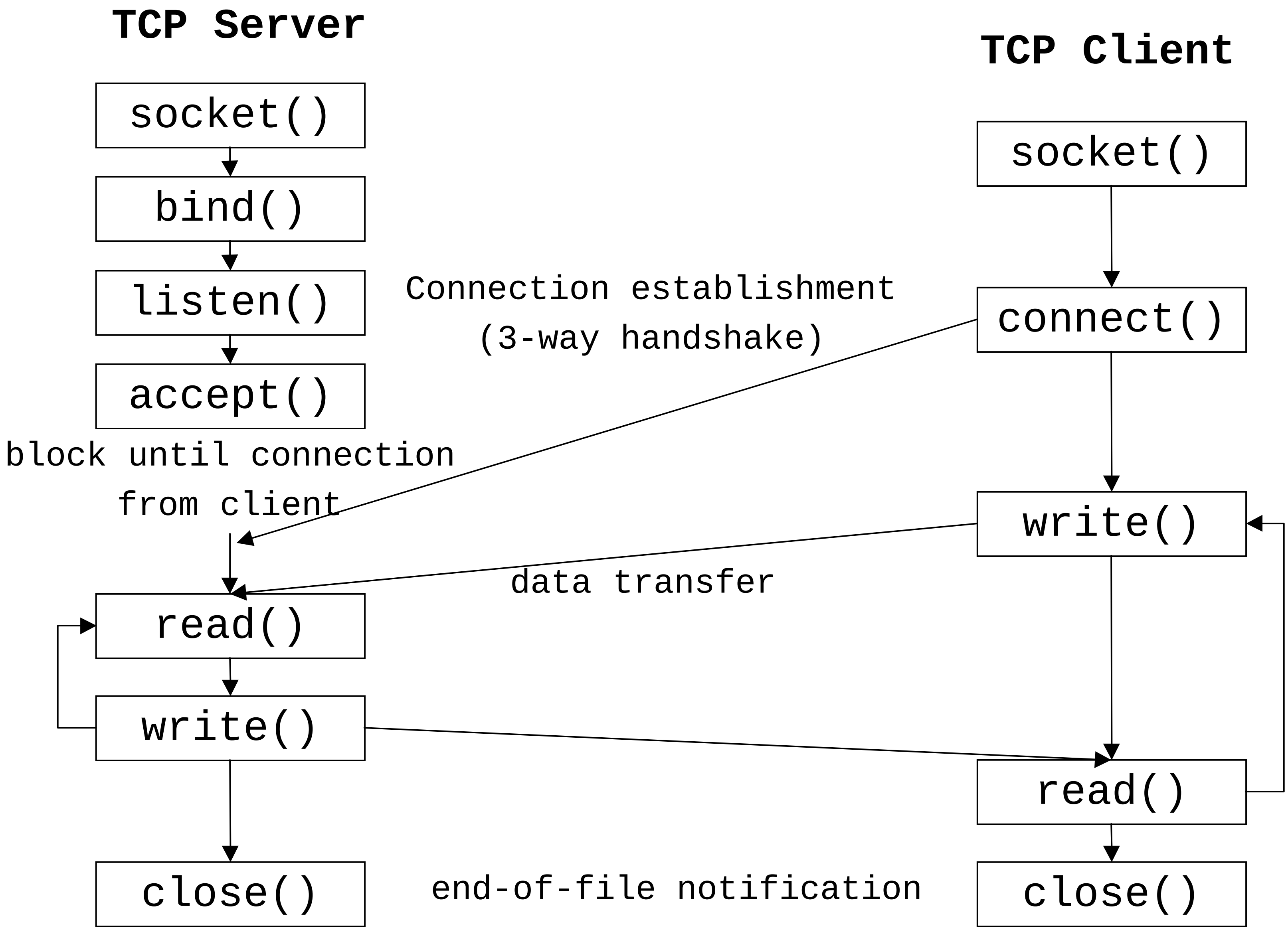
Addresses and Ports

- A socket pair is the two endpoints of the connection.
- An endpoint is identified by an IP address and a port.
- IPv4 addresses are 4 8-bit numbers:
  - 128.100.31.200 = werewolf
  - 128.100.31.201 = seawolf
  - 128.100.31.202 = skywolf
- Ports
  - because multiple processes can communicate with a single machine we need another identifier.

More on Ports

www.iana.org

- Well-known ports: 0-1023
  - 80 = web
  - 22 = ssh
  - 23 = telnet
  - 21 = ftp
  - 25 = smtp (mail)
  - 194 = irc
- Registered ports: 1024-49151
  - 2709 = supermon
  - 26000 = quake
- Dynamic (private) ports: 49152-65535
  - You should pick ports in this range to avoid overlap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Server side

```
int socket(int family, int type,
           int protocol);
```

- family specifies protocol family:
  - `PF_INET` – IPv4
  - `PF_LOCAL` – Unix domain
- type
  - `SOCK_STREAM`, `SOCK_DGRAM`, `SOCK_RAW`
- protocol
  - set to 0 except for RAW sockets
- returns a socket descriptor

bind to a name

```
int bind(int sockfd,
      const struct sockaddr *servaddr,
      socklen_t addrlen);
```

- sockfd – returned by socket
- `struct sockaddr_in {`

```
    short           sin_family; /*AF_INET */
    u_short         sin_port;
    struct in_addr  sin_addr;
    char            sin_zero[8]; /*filling*/
  };
```

- `sin_addr` can be set to `INADDR_ANY` to communicate with any host

Set up queue in kernel

```
int listen(int sockfd, int backlog)
```

- after calling `listen`, a socket is ready to accept connections
- prepares a queue in the kernel where partially completed connections wait to be accepted.
- `backlog` is the maximum number of partially completed connections that the kernel should queue.

Complete the connection

```
int accept(int sockfd,
        struct sockaddr *cliaddr,
        socklen_t *addrlen);
```

- blocks waiting for a connection (from the queue)
- returns a new descriptor which refers to the TCP connection with the client
- `sockfd` is the listening socket
- `cliaddr` is the address of the client
- reads and writes on the connection will use the socket returned by accept

Client side

- `socket()` – same as server, to say “how” we are going to talk

```
int connect(int sockfd,
      const struct sockaddr *servaddr,
      socklen_t addrlen);
```

- the kernel will choose a dynamic port and source IP address.
- returns 0 on success and -1 on failure setting errno.
- initiates the three-way handshake.

inetclient.c

> most error checking is omitted in this example

```
int soc;
struct hostent *hp;
struct sockaddr_in peer;

peer.sin_family = AF_INET;
peer.sin_port = htons(PORT);
/* fill in peer address */
hp = gethostbyname(argv[1]);
peer.sin_addr = *((struct in_addr *)hp->h_addr);
/* create socket */
soc = socket(PF_INET, SOCK_STREAM, 0);
/* request connection to server */
if (connect(soc, (struct sockaddr *)&peer, sizeof(peer))
       == -1) {
  perror("client:connect"); close(soc); exit(1);
}
write(soc, "Hello Internet\n", 16);
read(soc, buf, sizeof(buf));
printf("SERVER SAID: %s\n", buf);
close(soc);
```

inetserver.c

full code for this example is on the webpage

```
struct sockaddr_in peer;
struct sockaddr_in self;
int soc, ns, k;
int peer_len = sizeof(peer);

self.sin_family = AF_INET;
self.sin_port = htons(PORT);
self.sin_addr.s_addr = INADDR_ANY;
bzero(&(self.sin_zero), 8);

peer.sin_family = AF_INET;
/* set up listening socket soc */
soc = socket(PF_INET, SOCK_STREAM, 0);
if (soc < 0) {
  perror("server:socket"); exit(1);
}

if (bind(soc, (struct sockaddr *)&self, sizeof(self))== -1){
  perror("server:bind"); close(soc); exit(1);
}
listen(soc, 1);
...
```

inetserver.c (concluded)

```
/* ... repeated from previous slide ...
  soc = socket(PF_INET, SOCK_STREAM, 0);
  bind(soc, (struct sockaddr *)&self, sizeof(self))== -1){
    perror("server:bind"); close(soc); exit(1);
  }
  listen(soc, 1);
... and now continuing ... */

  /* accept connection request */
  ns = accept(soc, (struct sockaddr *)&peer, &peer_len);
  if (ns < 0) {
    perror("server:accept"); close(soc); exit(1);
  }
  /* data transfer on connected socket ns */
  k = read(ns, buf, sizeof(buf));
  printf("SERVER RECEIVED: %s\n", buf);
  write(ns, buf, k);

  close(ns);
  close(soc);
```

Byte order

- Big-endian

91,329 =

A	A+1	A+2	A+3
00	01	64	C1

- Little-endian

91,329 =

A+3	A+2	A+1	A
00	01	64	C1

- Intel is little-endian, and Sparc is big-endian

Network byte order

- To communicate between machines with unknown or different “endian-ness” we convert numbers to network byte order (big-endian) before we send them.
- There are functions provided to do this:
  - `unsigned long htonl(unsigned long)`
  - `unsigned short htons(unsigned short)`
  - `unsigned long ntohl(unsigned long)`
  - `unsigned short ntohs(unsigned short)`

Sending and Receiving Data

- `read` and `write` calls work on sockets, but sometimes we want more control
- ```
  ssize_t send(int fd, const void *buf,
               size_t len, int flags);
  ```
  - works like `write` if `flags==0`
  - flags: `MSG_OOB`, `MSG_DONTROUTE`, `MSG_DONTWAIT`
- ```
  ssize_t recv(int fd, void *buf,
               size_t len, int flags);
  ```
  - flags: `MSG_OOB`, `MSG_WAITALL`, `MSG_PEEK`